NEONATAL OSTEOMYELITIS

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To My Teachers

ACKNOWLEDGEMENTS

I would like to thank Dr E B Hoffman for his support and enthusiasm, Professor A W B Heywood and Mr M Singer for their guidance and Michael Wyeth for the illustrations.

This dissertation is based largely on an original study performed by myself and Dr E B Hoffman on 34 neonates with bone and joint sepsis. Our experience of 19 septic hips is the largest in the literature. The study was performed at the Red Cross Children's Hospital in 1987 and 1988. The paper has been accepted for publication in the Journal of Bone and Joint Surgery (September 1990).
The literature has been reviewed in depth and compared with our findings. In order to avoid repetition, I have not included a separate literature review in my dissertation. I have however incorporated the literature review in the introduction and especially in the discussion.

The dissertation is presented as follows:

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NEONATAL OSTEOMYELITIS

1. INTRODUCTION AND INCIDENCE

It has been known for many years that acute haematogenous osteomyelitis varies in its clinical characteristics according to the age of the patient; thus osteomyelitis of the infant, child and adult constitute 3 separate clinical conditions. Trueta (1959) attributed the different clinical and pathological features in the 3 age groups to the differing vascular arrangements in the bone. In the first 6 months of life, Trueta (1959) noted that vessels from the metaphysis penetrated the growth plate to reach the epiphysis. Trueta (1959) suggested that this accounted for frequency of infections of the joint and of the epiphyseal side of the physis in the infant. More recently Chung (1976) has refuted this and shown that in the normal neonatal hip, the physis constitutes an almost absolute barrier to blood flow between the metaphysis and epiphysis. Clearly other factors play a role.

In 1874 Thomas Smith described 22 cases of septic arthritis and osteitis affecting infants, i.e. within the first year of life. 13 died and the 9 survivors were left with a destroyed epiphysis, a short limb and flail joint - the archetype cripple.

This study analyses only those cases of bone and joint sepsis occurring in the first 28 days of life. Osteomyelitis in the neonatal period is rare. Fraser (1924) reported 30 cases in the pre antibiotic era; Dennison (1955) reviewed 19 cases treated between 1945 and 1951 in the Royal Hospital for Sick Children, Glasgow; Murray Clarke (1958) reported 24 cases that were managed over 5 years at the Royal Children's Hospital, Melbourne. More recently Weissberg et al (1974) analysed the clinical features of 17 neonates with osteomyelitis who were admitted to the Children's Hospital Medical Centre, Boston over a 7 year period. Bergdahl et al (1985) has reported the largest series to date - 40 neonates treated at St. Goran's Children's Hospital in the years 1970-1979.

The clinical features of neonatal osteomyelitis differ significantly from infections occurring in older children (Murray Clarke 1958; Lloyd-Roberts 1979). This, together with the rarity of the condition, frequently contributes to a delay in diagnosis in the neonate (Obletz 1960). Fraser (1924) reported that osteomyelitis of the neonate was almost invariably fatal, but in the post antibiotic era survival rates have increased dramatically. Dennison (1955) reported 4 deaths in 19 cases, while Mok et al (1982) and Bergdahl et al (1985) reported no deaths in their series.

However, the survivors are frequently left with permanent bone and joint damage. Bergdahl et al (1985) found that 60% of patients were symptom-free at a mean follow-up of 4.3 years. Several of this group had radiographic and/or clinical changes but as they were symptom-free were assessed to have a favourable result. 40% had significant sequelae. The hip is especially at risk with a reported incidence of poor results between 50% (Bergdahl et al - 1985) to 80% (Hallel and Salvati - 1978). Wilkinson (1952) suggested that the fate of the hip, if involved, is sealed from the outset.

At the Red Cross Children's Hospital we treat a significant number of children with neonatal osteomyelitis (on average 3 cases per year). In 1988 10 neonates with osteomyelitis were treated at the Red Cross Children's Hospital.

A retrospective study was performed over a 10 year period, firstly to highlight the clinical and radiographic features of the disease and to create an awareness of this condition in order to aid early diagnosis. Secondly we wanted to assess our management protocol and long term results in comparison with those in the literature.

2. PATIENTS AND METHODS

34 neonates (≤28 days old) with osteomyelitis were treated at the Red Cross Children's Hospital between 1977 and 1987; an average of 3 patients per year. Infection was confirmed by a positive blood culture or the finding of pus at surgery or radiographic changes (metaphyseal rarefaction, periosteal reaction).

The clinical records and radiographs of all patients were analysed retrospectively.

The age at presentation, predisposing factors, clinical features (general and local) at initial presentation, sites affected, radiographic features, bacteriology and management protocol were all studied. All patients were seen post-infection as outpatients for a minimum period of 12 months. The average follow-up was 43 months (range 1 year - 12 years).

27 of the 34 neonates (79%) were available for long-term follow-up and were reviewed personally by the authors. Patients were examined for clinical deformity, limb length discrepancy, joint stability and range of movement. Radiographs were taken and assessed for epiphyseal, physeal and metaphyseal damage as well as for angular deformities. Of the 7 patients (21%) not personally seen at review, clinical records and radiographs were available for assessment in all cases. The details of these 7 patients are given in Table I.

TABLE I

Patients reviewed only by Clinical Records and Radiographs

Patient	Site	Clinical and Radiographic Outcome
A.A	Proximal femur/ hip	Destroyed capital epiphysis at 24 months
J.S.	Proximal femur/ hip	Destroyed capital epiphysis at 22 months
I.N.	Distal femur/knee	Normal at 12 months
S.C.	Distal femur/knee	Normal at 12 months
B.O.	Proximal tibia	Normal at 12 months
E.N.	Proximal tibia	Normal at 12 months
G.Z.	Distal humerus	Normal at 12 months

3. RESULTS

Age at Presentation

The average age at presentation was 23 days (range 8 - 28). No neonate presented in the first week of life.

Predisposing Factors

These were present in 22 neonates (65%) and are listed in Table II.

Clinical Features

Based on the "general" findings, 2 groups of neonates were identified. 26 neonates (76%) were not acutely ill at the time of presentation. 24 of the 26 were apyrexial and the remaining 2 had a minor pyrexia. Parents were not alerted to the severity of the condition and this accounted for a delay in presentation (average 10 days) in 13 patients. These patients constituted Group 1.

The remaining 8 neonates (24%) were acutely ill at initial presentation. 6 were septicemic and 2 had meningitis. In this group of ill neonates, who constituted Group 2, attention was focused on the systemic illness and the subtle local abnormalities were frequently overlooked. There was on average a delay of 5 days before the diagnosis was made.

Subtle "local" abnormalities were found in every case and are listed in Table III. The most frequent findings were swelling and pseudoparalysis (Fig. 1) of the involved limb, affecting 95% of involved limbs.

TABLE II

Predisposing factors in 22 neonates (65%)

Predisposing factors	Number of patients
Prematurity	7
Skin/umbilical sepsis	7
Delivered by caesarian section (1 premature)	6
Significant jaundice (2 premature)	4
Pneumonia	2
Meningitis	1

More than 1 predisposing factor was present in 5 neonates.

TABLE III

Local abnormalities present in 34 neonates (100%)

Local Finding	Number of patients
Pseudoparalysis	26
Swelling	25
Pain on passive movement	20
Abnormal posture	12

At least 1 abnormality was detected in every patient and 95% of patients had either pseudo-paralysis and/or swelling.

Figure 1

Neonate with involvement of the left proximal humerus/shoulder and pseudoparalysis of the left arm.

Sites

There were 42 sites of sepsis in 34 neonates. The most frequent site involved was the hip (45%). In 6 cases (18%) multiple sites were involved (Fig. 2).

Radiographic Changes

Radiographic abnormalities (subluxation, metaphyseal rarefaction, periosteal reaction) were noted on the initial radiograph at first presentation in 34 of the 42 sites (80%). (see Table IV)

18 of the 19 hips (95%) were subluxed and/or showed metaphyseal changes in the proximal femur at presentation (Fig. 3). Subluxation of the hip was defined as a gap of greater than 5mm between the proximal femur and ischium (Bertol, Macnicol and Mitchell 1982) on an AP radiograph of the pelvis taken with the legs symmetrically placed.

Bacteriology

The infective agent was cultured from blood or pus in 25 patients (74%). Staphylococcus aureus was the most commonly recognised organism (18 patients - 72%). Beta Haemolytic Streptococcus was the only other infective agent cultured (7 patients - 28%). 6 of these were Group B Streptococcal infections while 1 was Group A. There were no gram negative infections in our series. 5 of the Staphylococcal infections (30%) were resistant to Cloxacillin but sensitive to Fucidic Acid. These infections occurred in premature neonates who had been previously hospitalised.

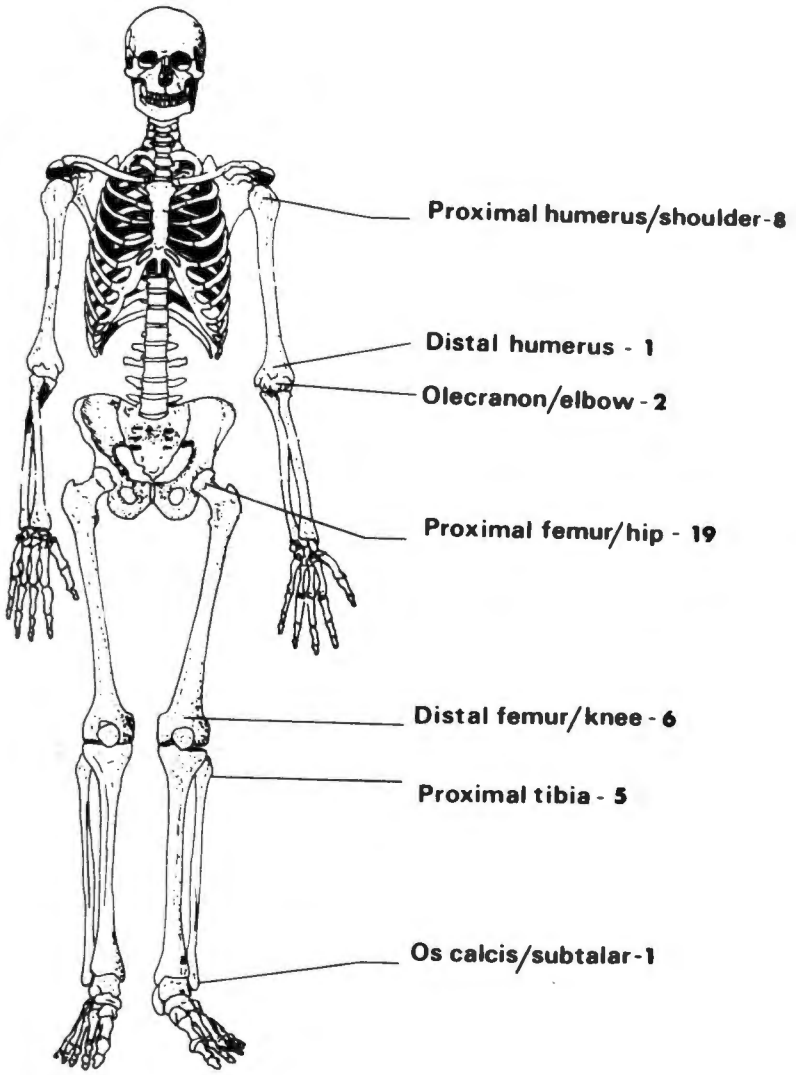

Figure 2

42 sites of sepsis in 34 neonates.

TABLE IV

Radiographic abnormalities noted at initial presentation

Sites	Number of patients with radiographic abnormalities	Radiographic findings
Proximal femur/hip	18/19	14 subluxed 12 rarefaction of metaphysis 8 both of the above
Proximal humerus/ shoulder	6/8	4 subluxed 4 rarefaction of metaphysis 2 both of the above
Distal femur/knee	4/6	4 rarefaction of metaphysis
Proximal tibia	5/5	4 rarefaction of metaphysis 3 periosteal reaction 2 both of the above
Distal humerus	1/1	1 rarefaction of metaphysis
Olecranon/elbow	1/2	1 rarefaction of metaphysis
Calcaneum/subtalar	1/1	1 rarefaction of metaphysis

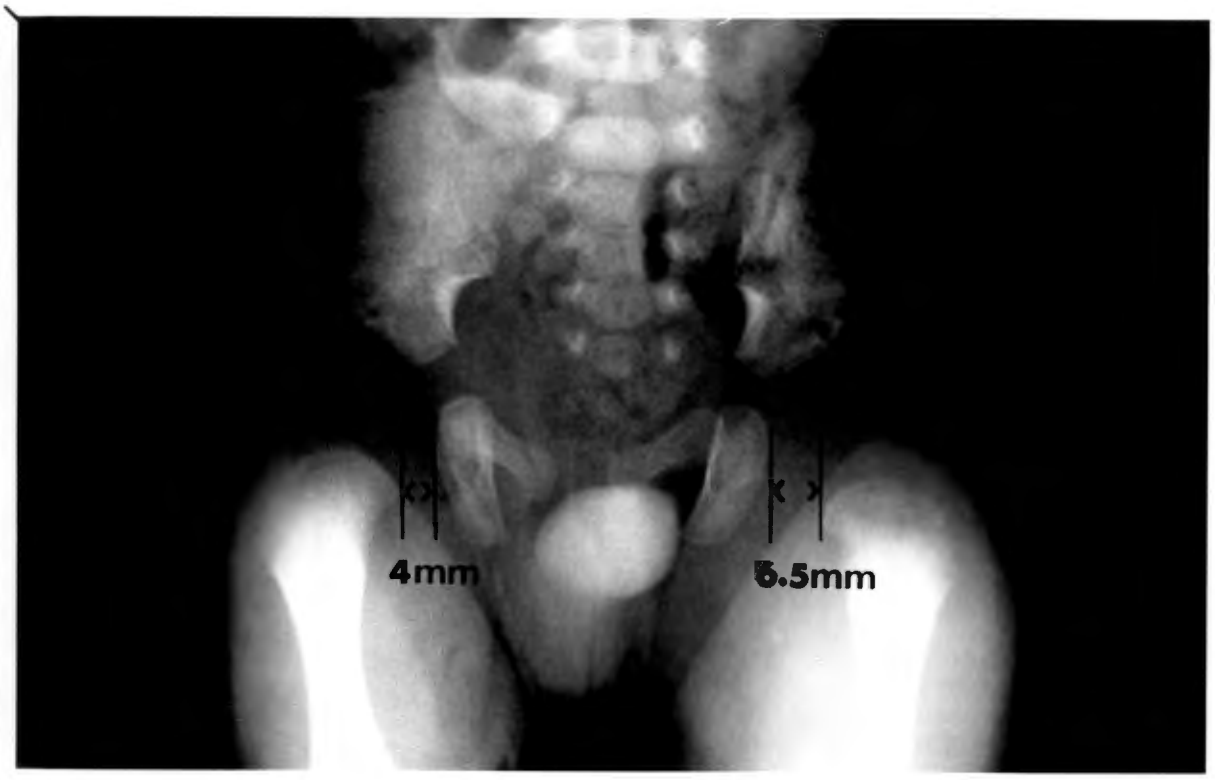

Figure 3

Neonate with involvement of the left proximal femur/hip. Note the metaphyseal rarefaction of the proximal femur and a medial gap between the ischium and proximal femur of greater than 5mm.

Management

All patients were admitted and treated with intravenous Cloxacillin (200 mg/kg/day) for a minimum of 48 hours, following routine blood culture. Oral antibiotics were continued for 6 weeks. Antibiotic therapy was adjusted according to the sensitivity of the organism (Penicillin - Streptococcus; Fucidic Acid - Cloxacillin-resistant Staphylococcus). 4 patients with an osteomyelitis not involving a joint, responded to early appropriate antibiotics alone. The remaining 30 patients underwent open surgical drainage (no aspiration was performed). The hip joint was always approached via an anterior Luck approach. The 19 hips were splinted in abduction for an initial period of 4 weeks post drainage. 10 of the 19 hips (53%) were persistently dislocated at the end of the 4 week period. These 10 hips were then treated with additional abduction splintage for a further 3 months. 6 of these hips became located with a normal capital epiphysis. The 4 hips that remained dislocated were those with a destroyed capital epiphysis.

Outcome

There were no deaths in this series. The fate of all sites of sepsis, excluding the hips is given in Table V. 75% of shoulder infections resolved without sequelae. The 2 shoulders with a destroyed epiphysis retained a near full range of movement at follow up. All infections of the distal femur and proximal tibia resolved completely with no leg length discrepancy, no angular deformity and a normal or near normal physis and epiphysis (Figs. 4A, 4B, 5A, 5B). Infections of the proximal tibia were never associated with a septic arthritis of the knee, while 4 of the 6 distal femoral infections were complicated by a septic arthritis of the knee.

The 19 hips were assessed using the classification of Hallel and Salvati (1978). Details of this classification and the long term results are given in Table VI. (Figs. 6A, 6B, 7, 8).

13 hips (68%) had a normal or mildly out of round head and were assessed as excellent (Group 1).

In 2 cases the head was small and there was a varus deformity of the proximal femur (Group 2). The femoral head was destroyed in 4 cases (Group 3). The 6 hips (32%) in Groups 2 and 3 were assessed to be poor results.

TABLE V

Outcome of all infections, excluding hips

Site	Number of patients	Findings
Proximal humerus/shoulder	6	Normal shoulder
	2	Destroyed epiphysis
Distal femur/knee	6	Normal femur/knee
Proximal tibia	5	Normal tibia
Olecranon/elbow	1	Normal elbow
	1	Dislocated radial head
Distal humerus	1	Normal humerus
Calcaneum/subtalar	1	Flat topped talus

Figure 4A

Neonate with proximal tibial osteomyelitis at 4 month follow-up. Note the anterior bowing of the tibia.

Figure 4B

Complete restoration of the tibia at 58 month follow-up.

Figure 5A

Neonate with involvement of the right distal femur/knee. Pus was drained from the joint.

Figure 5B

Minimal metaphyseal changes at 39 month follow-up.

TABLE VI

Outcome of the 19 hips using the classification of Hallel and Salvati

Number of Patients	Group	Findings
13	1	Normal capital epiphysis or out of round
2	2	Deformed small head/neck in varus position
4	3	Destroyed capital epiphysis

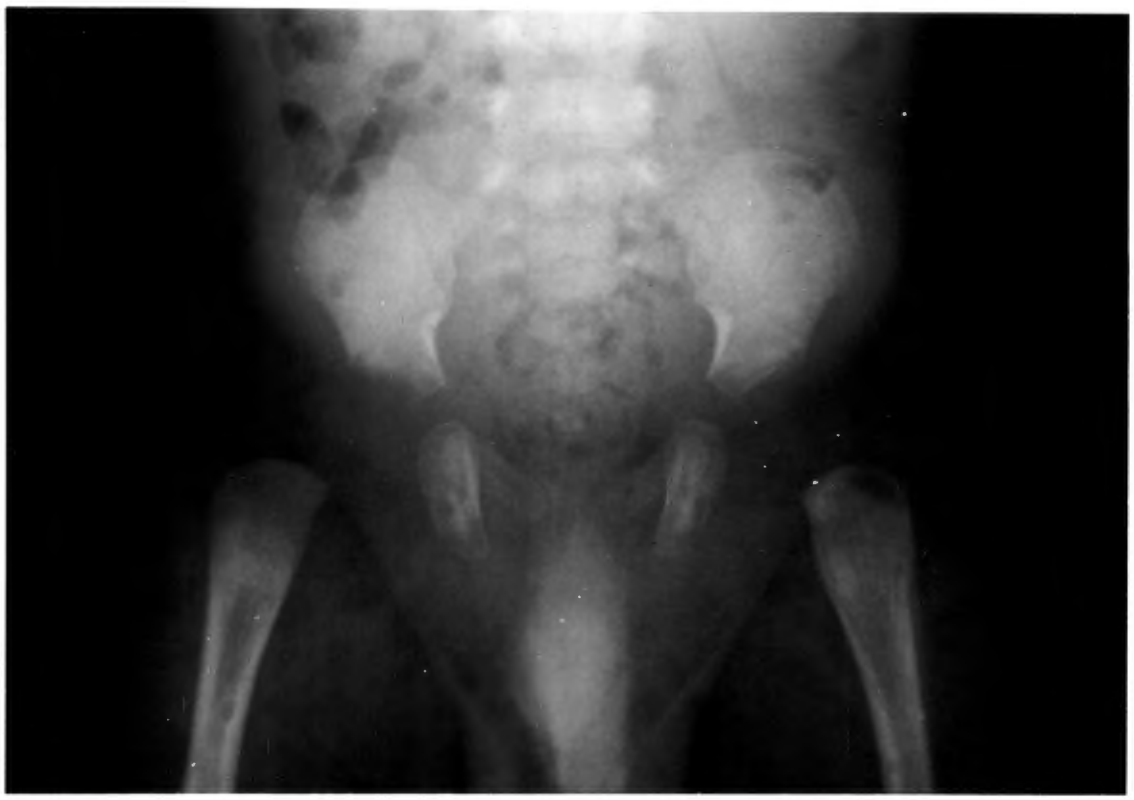

Figure 6A

Neonate with bilateral involvement of the proximal femur/hip with bilateral subluxation and metaphyseal rarefaction of the left proximal femur. Pus was found at operation in both hips.

Figure 6B

Both hips (patient seen in Fig. 6A) showing excellent results at 46 months. (Hallel and Salvati, Group 1).

Figure 7

Neonate at 50 month follow-up with a varus of the left femoral neck. (Hallel and Salvati, Group 2).

Figure 8

Neonate at 34 month follow-up with a destroyed left capital epiphysis, confirmed at arthrotomy. (Hallel and Salvati, Group 3).

4. DISCUSSION

Age at Presentation

Obletz (1960) reported 1 of the 16 neonates with hip sepsis presented in the first week of life. Bergdahl et al (1985) reported a 10% presentation in the first week of life. No neonate presented in the first week of life in our series. This suggests that intrauterine sepsis is an uncommon cause of neonatal osteomyelitis. Alternative diagnoses such as birth trauma may account for pseudoparalysis and swelling in the first week of life, while congenital syphilis may mimic the radiographic changes. These alternatives should be especially considered in the first week of life.

Predisposing Factors

Traditionally umbilical sepsis and skin infections have been the most common predisposing factors in neonatal osteomyelitis (Fraser 1924; Green and Shannon 1936). Skin infections may arise from scalp monitors, heel venupunctures, circumcisions, eczematous lesions etc. Although in our series, skin and umbilical sepsis was present in 7 cases, problems such as prematurity, Caesarian section and jaundice, which subject the neonate to hospitalization and invasive procedures are as common. This is in agreement with the findings of Weissberg et al (1974) and Bergdahl et al (1985).

Clinical Syndromes

Greengard (1946) was the first to recognise 2 distinct clinical syndromes in neonatal osteomyelitis. A benign form where the child is not systemically ill and a severe form where the child is septicaemic and the osteomyelitis is an incident in the disease process. A similar grouping was found by Hutter (1948) and Potter (1954). Thomson and Lewis (1950) and Dennison (1955) pointed out that the word benign only relates to the clinical picture of the neonate and is hardly a satisfactory description of a condition which may lead to permanent disability. Our findings support their opinion. In our group of patients who were systemically ill at presentation (Group 2), all 8 survived and 5 recovered without permanent bone and joint damage. Of the 26 neonates who were not systemically ill at presentation (Group 1), 5 suffered permanent bone and joint damage.

The major importance of separating the neonates into 2 groups is our finding that there is a frequent delay in diagnosis in the severely ill patient as the attention of the attending physician is not focussed on the osteomyelitis. The severely ill neonate may present with a non specific problem such as diarrhoea, failure to feed, lethargy etc. or may present with a non skeletal systemic infection such as pneumonia or meningitis (as in 2 cases in our series).

The fact that the majority of neonates are not systemically ill at presentation accounts for their late presentation, as the parents are not alerted to the seriousness of their condition.

Why two clinical syndromes exist is uncertain. The following two possibilities can be considered:

1. A different phage type of Staphyloccus aureus as the causative organism, and that this phage type does not only have an affinity for the metaphysis of bone, but also for the other sites such as the lung or meninges, and that this phage type may produce toxins responsible for the severe systemic reaction, as seen for example in the toxic shock syndrome.

2. Kuo et al (1975) have shown immunodeficiency (mainly a transient low IgA) in 60% of cases with infantile bone infection. They also showed a higher incidence of femoral head destruction with immunodeficiency. We found an increase in bad results in the severely ill patients (3 out of 8 = 38%, compared to 5 out of 26 = 19%). One would expect a more subdued clinical response in the immunodeficient patient, accounting for the delay in diagnosis in Group 1 patients, but an even more severe immunodeficiency may be responsible for the overwhelming infection seen in the severely ill patient in Group 2.

Diagnosis

The importance of early diagnosis has been emphasized by others (Obletz 1960, Lloyd-Roberts 1979). Early diagnosis allows early treatment. Obletz (1960) found, that in all 8 neonates in whom the hip joint was destroyed, there was a delay of between 4 to 16 days from the onset of hip sepsis to the onset of treatment.

The variable general presentation makes early diagnosis difficult. As isotope scanning is usually unreliable in the neonate (Ash and Gilday 1980; Bergdahl et al 1985), attention must be focussed on the subtle local and radiographic abnormalities. Awareness of the possibility of osteomyelitis and the need for diligence in detection of the local signs are essential for early diagnosis. We found, as have Blanche (1952), Obletz (1960) and Weissberg (1974) that swelling and pseudoparalysis (confirmed by pinching the involved limb) remained the most significant signs and that one or more of these signs is invariably present. Other significant local findings noted were pain on movement of the limb (with dressing or bathing and with local examination) and an abnormal posture, especially flexion if the hip is involved.

Unlike the older child with joint sepsis, in whom the infected joint is held frozen, it is possible in the neonate and infant to obtain a reasonable range of movement, despite sepsis. This must not be misinterpreted.

Although the white cell count was elevated in some cases, it was within normal limits in others and was of limited value in establishing the diagnosis. This concurs with the findings of Bergdahl et al (1985).

However the sedimentation rate was significantly elevated (average 72 mm). Moodley (1981) reported a rise in the sedimentation rate of normal neonates from 1.5 mm in the first week of life to 10 mm by the end of the neonatal period. These values are significantly lower than the rates in osteomyelitis.

Radiographic abnormalities were extremely useful in confirming the diagnosis. Unlike the older child in whom radiographic changes at presentation are the exception rather than the rule, 95% of involved hips showed abnormalities at initial presentation (lateral subluxation and/or metaphyseal rarefaction). Hutter (1948) was the first to describe lateral displacement of the hip. Obletz (1960) found this sign to be present in all cases and Bergdahl et al (1985) in most cases of hip sepsis.
The early metaphyseal rarefaction in the neonate may be explained by the softer bone in this age group, while the lateral subluxation may result from distention of the capsule with pus. Lloyd-Roberts (1979) has postulated that in the presence of a metaphyseal infection, the surrounding tissues (including the capsule) become lax and oedematous. The adductors and hip flexors develop reflex spasm and this

combination may account for the lateral subluxation of the hip when there is no pus in the joint.

We now regard lateral subluxation as such an important diagnostic clue, that we suggest every septicaemic neonate undergo a routine pelvic radiograph to screen for occult hip sepsis. In addition, it is our current practice to subject all neonates with osteomyelitis involving the lower limb, to a routine pelvic radiograph. The subtle local signs in the hip may be masked by simultaneous sepsis at a distal site in the ipsilateral limb.

Pathology

The pathology of neonatal osteomyelitis has been well described by Ogden and Lister (1974). Initially the septic focus is localised in the metaphysis adjacent to the growth plate. This area in the neonate is extremely weak bone compared to that of an older child and can be readily broken down by an inflammatory process. The infectious process can be decompressed by breaking through the thin cortex, thus gaining entry to the subperiosteal space and surrounding soft tissues. The periosteum, loosely attached and possessed of exceptional osteogenic potential, is rapidly elevated and almost immediately lays down exuberant callus (Lloyd-Roberts 1979).This is reflected in the early radiographs.

The joint and/or epiphysis may become involved by several routes:

1. The infectious process may gain access to the joint if some portion of the metaphysis is intra-articular. This is especially true in the hip joint and is the mechanism by which the joint in the older child becomes involved secondary to metaphyseal osteomyelitis.

2. Whether transphyseal vessels exist is controversial. Trueta (1959) and Ogden and Lister (1975) have shown transphyseal vessels between the metaphysis and epiphysis which remain open and cross the growth plate in the first year of life. After this period the growth plate is a barrier to spread. Chung (1976) in an extensive study

could not show any vessels crossing the growth plate even in neonates. Alderson, Speers, Emslie and Nade (1986) showed in ultrastructural studies of avian models that transphyseal vessels were present. They also showed that not only can the infection spread from the metaphysis to the joint via the growth plate, but also that primary joint infection can spread via the epiphysis and growth plate to the metaphysis, so that in cases of a septic arthritis with bony changes on radiographic examination it cannot be concluded with certainty whether the primary infection started in the metaphysis or the synovium.

3. Once the infectious process occupies the metaphyseal and epiphyseal sides of the growth plate, it can render the growth plate ischaemic, making it more susceptible to destruction and creating another route of spread (Ogden and Lister 1975).

The result of this epiphyseal invasion by the infectious process is destruction of the epiphysis, if not halted in time. The direct invasion of the epiphysis may account for the greater degree of epiphyseal destruction within the neonatal and infantile period. The fact that the epiphysis consists of relatively more cartilage than bone in early life may also make it vulnerable to greater damage. Epiphyseal destruction is seldom seen in the older child, in whom a poor result is reflected by chondrolysis and ankylosis as opposed to epiphyseal destruction.

It is also possible that avascular necrosis plays a role in the destruction of the epiphysis in the neonate. Chung (1976) emphasized that the main blood supply to the femoral head is provided by the lateral ascending cervical arteries which arise from a single-stem artery. This stem crosses the capsule at the trochanteric notch and is vulnerable to occlusion by compression. The neonate may be at greater risk than the older child for this complication.

In our series 32 out of 42 sites involved a joint (i.e. all 19 hips; 6 of the 8 proximal humeri had shoulder involvement; 2 olecranons had elbow involvement; 4 of the distal femurs had knee involvement and the calcaneus also involved the subtalar joint). The other 10 sites had metaphyseal involvement without concomitant joint involvement. Four of these sites (2 proximal humerii and 2 proximal tibiae) did not require surgical drainage, as they had early antibiotic treatment. Except for one exception (knee), all sites of joint involvement showed radiographic signs of osteomyelitis (metaphyseal rarefaction, periosteal reaction) or developed these changes subsequently. Fabry and Meire (1983) reported 2 out of 16 hips while Obletz (1960) found 1 out of 15 hips without bony changes on radiographic examination.

Alderson, Speers, Emslie and Nade (1986) have shown that it cannot be concluded whether the primary infection started in the synovium or the metaphysis and they therefore regard osteomyelitis and septic arthritis as a possible single

disease. The distinction between septic arthritis and osteomyelitis is therefore of little pathological significance. We believe, however, that the clinical diagnosis of pus in the joint is of the utmost importance, as aggressive surgical drainage of pus will prevent further destruction of the epiphyseal cartilage and also relieve compression of the ascending cervical arteries and prevent avascular necrosis.

Bacteriology

Weissberg (1974) also reported a predominance of Staphylococcal infections. Gram negative bacteria (E. Coli, Pseudomonas, Klebsiella etc.) have been responsible for a small percentage of infections in some series (Weissberg et al - 1977, Bergdahl et al - 1985), but were not found in our series. In 1989, the first case of neonatal osteomyelitis caused by a Gram negative bacteria (Klebsiella) was diagnosed at the Red Cross Children's Hospital.

Of the 10 sites with bad results in this series (6 hips, 2 shoulders, 1 elbow, 1 subtalar joint), 9 were due to Staphylococcal infections and 1 was due to a Streptococcal infection (Group A). Bergdahl et al (1985) found no difference in the sequelae of either organism.

Management and Outcome

The dramatic decline in mortality from neonatal osteomyelitis in the post-antibiotic era is a reflection of the efficacy of antibiotics in the control of septicemia. We believe that high dose intravenous Cloxacillin (200 mg/kg/day) is the best initial therapy in our environment, with the exception of the premature neonate who has been previously hospitalised. On the basis of our finding of a high incidence of Cloxacillin-resistant bacteria in this selected group of neonates, we would currently initiate treatment with Fucidic acid (30 mg/kg/day) in the previously hospitalised premature neonate.

We disagree strongly with Greengard (1946), Wilkinson (1952) and Nicholson (1960) that surgical drainage of pus should be limited. Antibiotics cannot replace surgical drainage. We concur with Blanche (1952), Obletz (1960) and Lloyd-Roberts (1979) that the hip joint should be decompressed by adequate open arthrotomy. Obletz (1960) aspirated the hip as a diagnostic procedure, but this has been shown by Paterson (1970) to be unreliable and is not recommended.

The favourable outcome of infections involving tibia and distal femur/knee has been reported by Trueta (1959) and Lloyd-Roberts (1960). Angular deformities of the tibial shaft (Fig. 4) corrected with time (Fig. 5) and no patient developed chronic osteomyelitis.

Involvement of the hip joint produces the most significant sequelae (Lloyd-Roberts 1960). Our series of 19 hips is the largest we could find in the literature (Blanche 1952 - 10; Hallel and Salvati 1978 - 18; Bergdahl et al 1985 - 17). These authors reported poor results ranging from 50% (Bergdahl et al - 1985) to 80% (Hallel and Salvati - 1978). Our results are significantly better (68% excellent). We believe our improved results are due to aggressive antibiotic treatment; immediate, adequate open surgical drainage and appropriate splintage. Evacuation of the pus decompresses the hip joint and may prevent obstruction of the important single-stem artery, which crosses the articular capsule at the posterior trochanteric fossa and divides to form the lateral ascending cervical vessels (Chung - 1976). In addition the destructive effect of the proteolytic enzymes on the articular cartilage is abolished.

Obletz (1960) used splintage for a varying period of between 3 weeks and 18 months. Lloyd-Roberts (1979) emphasized the importance of immobilizing the hip in a stable position of abduction and some flexion. The abduction splintage used in our series included broomstick plasters, Pavlick harnesses and Gallow's traction. We currently prefer the use of broomstick plasters as they achieve adequate abduction and provide hip stability and at the same time allow some hip flexion as well as ease of wound access.

Of the 19 hips in our series, 9 were clinically stable and radiographically located after a 4 week period of abduction splintage following incision and drainage. Splintage was then discarded and all 9 hips developed normally and remained stable.

10 hips (53%) were dislocated after 4 weeks of initial splintage. All 10 were treated with some form of abduction splintage for an additional 3 month period. 6 hips subsequently became stable and the 4 that remained unstable were those with the capital epiphysis destroyed. This finding is in accord with the view of Hallel and Salvati (1978) who reported that dislocated hips with minimal or moderate femoral head destruction have a good chance of being located by conservative means within the first 2 months of the septic process. It is likely that by 3 months sufficient capsular contracture has developed to provide stability of the hip. Failure to achieve a stable hip, despite 3 months of appropriate splintage is, we believe, highly suggestive of destruction of the capital epiphysis. Further splintage beyond 3 months post drainage is probably of little value.

Of the 10 bad results in this series, prematurity (5 patients, all infected with Cloxacillin-resistant Staphylococcus) was the most common associated factor. Kuo et al (1975) have shown an immature immune response in premature babies. Whether the prematurity and the poor immune response or the Cloxacillin-resistant Staphylococcus plays the major role in the unsatisfactory result is debatable.

Long Term Sequelae and their Management

If the hip appears to be unstable despite 3 months of appropriate abduction splintage, push-pull radiographs are the most reliable method to assess the location of the proximal femur (Hallel and Salvati 1978).

At this stage either the capital epiphysis is destroyed (and the hip resembles a Girdlestone arthroplasty) or the hip is dislocated with a partially intact capital epiphysis. The presence, shape and size of the proximal femur cannot be determined by plain radiographs in infancy. Ossification may in fact be delayed for several years.

As arthrography is an unreliable method to assess the state of the femoral head (Hallel and Salvati - 1978), the only way to reveal the presence or absence of the cartilagenous femoral head and neck is by surgical exploration. Hallel and Salvati (1978) recommend that this be delayed until 1 to 2 years of age when the structures are larger and it is easier to decide if there is sufficient femoral head and neck to achieve a stable reduction.

The same authors recommend that if at the time of exploration (i.e. 1 to 2 years of age), the shape and size of the proximal head/neck is adequate for reduction, it should be placed in the acetabulum after clearing the latter of scar tissue. They found that 2 of the 3 hips, in which this was performed, were stable, pain free and well functioning at a mean follow-up of 16 years.

Although their experience is limited, it would seem reasonable to follow this approach, as a much shorter limb and more significant Trendellenberg gait would develop if the proximal femur were allowed to dislocate and ride upwards.

It must be emphasized that this procedure is recommended only for those hips which have a reasonably well preserved capital epiphysis and that a stable reduction is thus possible. Proximal overgrowth of the greater trochanter may become conspicuous around the end of the first decade in those patients with a located but deformed femoral head/neck. A subtrochanteric valgus osteotomy was assessed by Hallel and Salvati (1978) to be a good option at about 10 years of age if the patient was troubled by painful limited abduction and a significant Trendellenberg gait.

The management of those hips resembling Girdlestone arthroplasties (i.e. with a destroyed femoral head and a high riding proximal femur) is controversial. Mitchell (1980) favoured relocation of the femoral "stump" together with innominate and in some cases femoral osteotomies in order to improve stability. Mitchell (1980) found arthrography to be useful to assess the femoral head and advocated preoperative skin traction. He emphasized the importance of adequate capsular excision and routine innominate osteotomy. At an average follow-up of 10 years, 6 of his 7 patients were pain free, stable and mobile.

Obletz (1962) and Fabry and Meire (1983) have suggested leaving the "Girdlestone" hip as it is.

Hallel and Salvati (1978) found a trochanteric arthroplasty to be successful in only 1 of 5 cases where the femoral head was absent. Fabry and Meire (1983) reported fair results in 2 patients and poor results in 3 patients following this procedure. A result was assessed to be fair, if there was a well located trochanter, only slight discomfort and relative stiffness of the hip joint. Of the 3 poor results, 1 hip was completely stiff and 2 had redislocated.

The advantages of a successful trochanteric arthroplasty or an open reduction of the femoral "stump" and innominate osteotomy, as compared to a complete dislocation are: greater stability, a less conspicuous abductor lurch, less limb length discrepancy and a better anatomic condition for later prosthetic reconstruction.

The disadvantages are restricted range of motion and increased chances of pain at an earlier age due to bony contact and secondary degenerative changes.

The predictability of the procedure is also questionable, as some hips may progress into subluxation or dislocation in spite of adequate surgery and postoperative immobilization. Finally some hips may ankylose after this procedure.

Wopperer et al (1988) provided important information on the natural history of those hips which were not subjected to reconstructive surgery. 3 dislocated hips with a destroyed capital epiphysis were followed for 30 years. Despite the obvious short limb and waddling gait, the hips were found to be pain free, fully functional and had almost full mobility (the patients were in their early thirties at review). While the future course of these patients is unknown, the results do suggest that it is reasonable in patients with painless high dislocations, to maintain a non operative approach until adolescence. At this stage a contra-lateral distal femoral epiphyseodesis may be performed to minimise the harmful effects of a gross limb length inequality. In the child with destruction of both hips, leg length inequality is not an issue, and a persistent conservative approach should be advocated.

The suggested management of the damaged hip can be summarised as follows.

PATHOLOGY	MANAGEMENT
Located hip, coxa vara	Valgus osteotomy (selective)
Dislocated hip, femoral head partially preserved	Open reduction +/- osteotomy
Destroyed femoral head	Leave as Girdlestone Arthroplasty

5. CONCLUSION

An awareness of neonatal osteomyelitis and a knowledge of the clinical and radiographic features of the disease at presentation makes early diagnosis and thus early treatment possible. Aggressive antibiotic therapy and immediate open drainage is the best method to preserve the femoral capital epiphysis. Splintage of the frankly dislocated hip should be continued for at least 3 months because a good result may be anticipated if the epiphysis is not destroyed. The fate of the infected neonatal hip is not sealed from the outset and these children are not doomed to spend life as a cripple.

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